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**(54) Document recognition apparatus**

(57) Document recognition apparatus for banknotes (1) utilises bar codes which are printed in fluorescent ink on the face of banknotes (1). The bar codes are read by transporting the notes past a reading station (4) where an ultra-violet lamp (5) illuminates the notes (1) and causes any barcoded information printed on them to fluoresce and be detected by a photodiode (9) sensitive to

the wavelength of the fluorescence. To ensure that the barcode is read irrespective of which way up a note is transported, and irrespective of which edge of the note leads, additional reading stations may be provided. To help read old and dirty notes, as well as to detect forgeries, the output of the photodiode may be fed to a neural network.

**EP 0 889 446 A2**

## Description

This invention relates to document recognition apparatus. It is concerned with the automatic recognition of banknotes and like documents.

Automatic teller machines (ATMs) which dispense banknotes to bank customers after a customer validation procedure are in world-wide use. It is desirable that such machines not only dispense banknotes but are also adapted to be capable of receiving, recognising and validating banknotes and as a result become able to accept banknotes fed to them by bank customers and thus to recycle them.

As a prerequisite to such recognition banknotes need to carry information in machine readable form. To this end the three Scottish banknote issuing banks have already introduced a common form of code marking on their notes, using the well-known barcode code. These markings encode the face value of banknotes and information identifying the issuing bank. The markings are printed in fluorescent ink which is invisible in normal light but fluoresces in ultra-violet light.

It is an object of the invention to provide apparatus capable of automatically recognising banknotes and like documents.

According to the invention apparatus for automatically recognising banknotes and like documents comprises document transport means for transporting such documents in succession past a reading station, radiation generator means for generating radiation and directing such generated radiation onto each successive document as it passes the reading station, and electronic read means for reading any information encoded on the document in machine readable form and which is responsive to such radiation.

Preferably the radiation generator means is positioned to transmit radiation through each document as it passes the reading station, the electronic read means is positioned to receive radiation emitted from such document and the transport means is arranged to pass documents between the radiation generator means and the electronic read means.

In carrying out the invention the electronic read means may be sensitive to light of a different predetermined wavelength to the generated radiation, which generated radiation may be in the ultra-violet region of the radiation spectrum. The said predetermined wavelength may be the emission wavelength of fluorescent ink with which documents to be read have code markings printed thereon, the fluorescent ink being sensitive to the ultra-violet radiation.

Documents to be read are likely in practice to be rectangular and have a pair of longer edges and a pair of shorter edges and the transport means is preferably adapted to orientate the documents so that either one of a predetermined pair of edges is the leading edge.

In embodiments of the invention a plurality of reading stations are preferably provided so positioned as to be able to read encoded information irrespective of which way up a document faces and irrespective of which of the edges of the predetermined pair is the leading edge..

In embodiments of the invention a learning system is used which learns from the information encoded on the documents which can be read by the read means so as to identify banknotes and similar documents. This has the advantage of reducing the complexity of the algorithm required to undertake the task which reduces the recognition time.

In order that the invention may be more fully understood reference will now be made to the accompanying drawings in which:

Fig. 1 illustrates diagrammatically a typical banknote of the kind which apparatus embodying the invention is intended to read,

Fig. 2a and Fig. 2b show a reading station as used in apparatus embodying the invention in plan view and end elevation respectively,

Fig. 2c shows a magnified detail of Fig. 2b,

Fig. 3 is a diagrammatic side view representation of reading stations as shown in Figs. 2a and 2b,

Fig. 4a and Fig. 4b show a banknote transport mechanism in side view and plan view respectively, and

Fig. 5 illustrates a neural network used in embodiments of the invention.

Referring now to Fig. 1 there is shown therein in diagrammatic form the front face 1 of a typical banknote as issued by a Scottish banknote issuing bank. In addition to the usual kind of visibly readable information printed on the note, including the name of the issuing bank, the face value or denomination of the note and security printing, coded information is printed in invisible ink which is fluorescent under ultra-violet radiation. The wavelength of the fluorescence peaks at 530nm in the green region of visible light. The coded information is printed in the form of a 13 element barcode with each bar 2mm by 26mm wide. The code is duplicated in two regions 2 and 3. The two regions 2 and 3 are positioned relative to centre lines parallel to the shorter and longer edges of the notes respectively so that the codes can be equally well read whether the leading edge of a note is a shorter or a longer edge. Each bar is either a "1" (fluorescent green) or a "0" (no fluorescence).

Regardless of the issuing bank the first two elements of the coded information are 1,0 and the final two are 0,1.

The nine elements in the middle represent the different banks and different denominations. Table 1 below sets out the codes for the various issuing banks and denominations.

Table 1

Issuing Bank	Denomination	Code
Clydesdale Bank	£5	1010001000101
Clydesdale Bank	£10	1011010110101
Clydesdale Bank	£20	1000101010001
Bank of Scotland	£5	1001011001101
Bank of Scotland	£10	1010010100101
Bank of Scotland	£20	1011011000101
Royal Bank of Scotland	£5	1011011111001
Royal Bank of Scotland	£10	1000010010001
Royal Bank of Scotland	£20	1011101011101

A reading station 4 for reading the encoded information printed on a banknote as shown in Fig. 1 is illustrated in Fig. 2a and Fig. 2b. Reading station 4 includes an ultra-violet tube 5 positioned to shine ultra-violet light onto a banknote 1 while it is being carried past the reading station by suitable transport means. An example of suitable transport means will be described below and is shown in Figs 4a and 4b. The transport means is arranged to move banknotes with a long edge leading and tube 5 is wide enough to ensure that ultra-violet light shines across the whole width of a banknote as it passes the reading station. Any fluorescent ink markings on banknote 1 emit light, and as mentioned above with reference to Fig. 1, the barcode markings on Scottish banknotes emit green light at wavelengths which peak at around 530nm.

To detect such light emitted from the barcode markings on note 1 an electronic read means 6 is provided at reading station 4. Read means 6 is positioned on the opposite side of a note passing through reading station 4 to tube 5 and immediately above tube 5. A magnified view of read means 6 is shown in Fig. 2c. Read means 6 comprises a plate 7 in which there is a housing 8 containing a photodiode 9 selected to have a peak response at around 550nm, close to the peak frequency of the fluorescent emission from banknote 1. Housing 8 includes a 1mm wide slot 10 through which light from banknote 1 passes to reach photodiode 9. To improve the signal-to-noise ratio of the signal detected by photodiode 9 an interference filter 13 (shown diagrammatically in Fig. 3) is provided in front of the photodiode to reduce the level of infra-red and low blue signals reaching diode 9.

There are four possible orientations of a note when at a reading station with a long edge leading and therefore four possible locations of the barcode information. For a banknote with its face upwards there are two possible locations. Read means 6 is positioned at one of them. A second electronic read means 11 similar to read means 6 is provided and which is parallel to read means 6 to read the barcode if it is at the second location. For the third and fourth possible locations of the barcode, which occur when a banknote faces the opposite way, a second reading station is provided which is similar the one described above but is positioned facing the opposite direction. This is shown more clearly in Fig. 3.

Fig. 3 shows a side view of two reading stations 4 and 4' positioned to read a barcode on a banknote 1 with a longer edge leading in all its possible orientations. Reading station 4 is provided with an ultra-violet lamp 5 backed by a reflector 12. Facing lamp 5 there is provided a read means (read means 6 in Figs. 2a and 2b) including a photodiode 9 and a filter 13. A further read means is positioned in line with read means 6 but will not be visible in Fig. 3. (The further read means is shown in Figs. 2a and 2b as read means 11.) Reading station 4' is identical in all respects with reading station 4 but is positioned the opposite way up so as to be able to read bar codes on those banknotes that pass through the apparatus with their faces the opposite way. In this way it is possible to ensure that a barcode on a banknote is read irrespective of its orientation, provided that a longer edge leads. If a shorter edge leads then a further four orientations are possible and two further reading stations, each having two read means will be required.

Reading station 4 has been described and illustrated as having a light source positioned on one side of note 1 and read means positioned on the opposite side of note 1 so that note 1 passes between them. However it is also possible to have the light source and the read means both positioned on the same side of a note as it passes a reading station.

Fig. 4a and Fig. 4b show banknote transport means used to carry banknotes past a reading station. The transport means has four tension-controlled drive belts 21, 22, 23 and 24. Drive belts 21 and 22 are above the path of the notes and drive belts 23 and 24 are below. (Belt 24 is not visible in the figures.) Upper belt 21 passes over wheels 25, 26 and 27 located on shafts 28, 29 and 30 that extend across the unit. Lower belt 23 passes over wheels 31, 32 and 33 located on shafts (not shown) which are underneath shafts 28, 29 and 30. Upper belt 22 passes over wheels which are also located on respective shafts 28, 29 and 30 but spaced apart along their respective shafts from wheels 25, 26

and 27. Lower belt 24 is positioned below upper belt 22 and is identical to lower belt 23 but is spaced laterally therefrom. The various shafts are driven by gears which are connected through a drive train to a source of motive power (not shown). Shafts 29 and 32 are spring loaded to maintain tension in the belts.

In use of the apparatus described above signals received from a photodiode at a reading station are divided serially into 13 equal segments corresponding to the 13 digit bar code printed on the banknotes and each segment is digitised by being applied to a threshold unit. Signals above a threshold are digitised as '1's and signals below the threshold are digitised as '0's. For clean valid notes this is sufficient to provide a signal corresponding to one of the codes set out in Table 1 and thus to give an indication of their face value and issuing bank. However the apparatus is required to respond to old and dirty notes. In such cases the '1's may be obliterated by dirt or degradation of the fluorescence and be translated as '0's. To overcome this problem as well as to detect forgeries a neural network may be used to process the output signals from the read means.

A back error propagation architecture neural network is illustrated in Fig. 5. It comprises a number of nodes arranged in layers. In the example shown a three-layer neural network is used, comprising an input layer 51, a middle layer 52 and an output layer 53. The number of nodes in the input layer corresponds to the number of inputs. (Four nodes are shown in input layer 51 by way of illustration.) In the example illustrated two nodes are provided in middle layer 52, but this number can be increased or decreased as required. For the output layer 53 the number of nodes corresponds to the number of different classes of output that are required. In Fig. 5 output layer 53 has four nodes provided, but this is purely by way of illustration. For the nine possible kinds of note listed in Table 1 nine output nodes are required if forgeries have already been rejected and eighteen output nodes are needed to cope with the possibility that each kind of note may be forged. In a neural network connections are made from every input node to every middle layer node and from every middle layer node to every output layer node. Each input connection to a node is weighted. Every node calculates the sum of its weighted inputs. The calculated sum is compared to a predetermined threshold for that node. If the sum is above the threshold then the output of that node is a '1', otherwise it is a '0'.

To enable a neural network to function it must be 'taught'. An example of a limited operational network is one which was taught to recognise all Scottish £20 banknotes issued by the three issuing banks and validate recognised notes by distinguishing between notes that are real and notes that are forged. There are thus six possible different positive results and the output layer of the neural network therefore requires six nodes. In addition there is the possibility that no fluorescence is detected so that a further 'zero' output may be provided. The required output codes from the output layer are set out below in Table 2.

Table 2

Banknote	Status	Output Code
£20 Bank of Scotland	valid	1 0 0 0 0 0
£20 Clydesdale Bank	valid	0 1 0 0 0 0
£20 Royal Bank of Scotland	valid	0 0 1 0 0 0
£20 Bank of Scotland	forgery	0 0 0 1 0 0
£20 Clydesdale Bank	forgery	0 0 0 0 1 0
£20 Royal Bank of Scotland	forgery	0 0 0 0 0 1

The number of input nodes in the above example was 13, with each input node receiving one segment of the thirteen segments into which the read signal is divided. The inputs to the respective nodes will correspond, for a perfectly read signal from a valid £20 note, to one of the digits of the code set out in Table 1 for that kind of note. A middle layer of four nodes was used and, as mentioned above, there were six output nodes.

For the learning process the network was initially started with the nodes having random weightings and thresholds and with known kinds of £20 note fed in. When the output signals were incorrect the weightings were adjusted by a back-propagation method in which firstly the output nodes and then the middle nodes were adjusted to reduce the error. This back-propagation 'learning' method can be controlled by suitable software. In practice it has been found that the barcodes of forged banknotes are sufficiently different from genuine notes to enable them to be distinguished therefrom by a suitably taught neural network. However if desired additional sensors to detect parameters other than barcode fluorescence can be provided for forgery detection. Such sensors can be positioned either before or after the barcode reading stations.

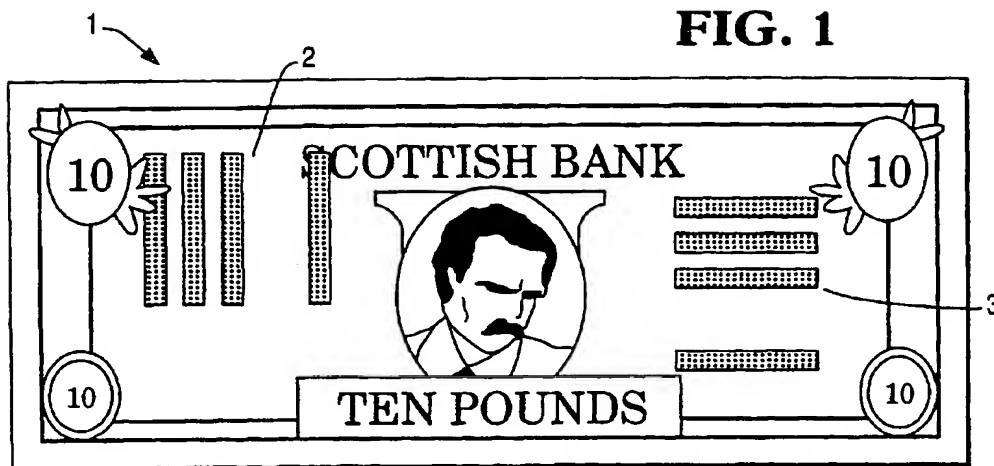
## Claims

1. Apparatus for automatically recognising banknotes and like documents comprising document transport means

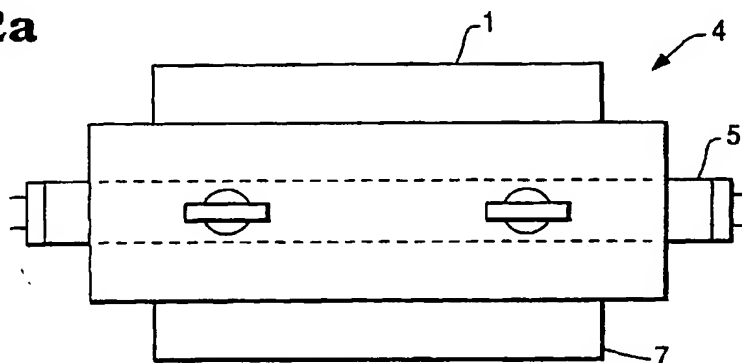
(Fig. 4a and Fig. 4b) for transporting documents (1) in succession past a reading station (4), radiation generator means (5) for generating radiation and directing such generated radiation onto each successive document (1) as it passes the reading station (4), and electronic read means (6) for reading information encoded on the document (1) in machine readable form and which is responsive to such radiation.

2. Apparatus as claimed in claim 1 in which the radiation generator means (5) is positioned to transmit radiation through each document (1) as it passes the reading station (4) and the electronic read means (6) is positioned to receive radiation emitted from such document (1).
3. Apparatus as claimed in claim 2 in which the transport means is arranged to pass documents between the radiation generator means (5) and the electronic read means (6).
4. Apparatus as claimed in any one of the preceding claims in which the radiation generator means (5) comprises an ultra-violet light source.
5. Apparatus as claimed in any one of the preceding claims in which the electronic read means (6) is sensitive to light of a different predetermined wavelength to the generated radiation.
6. Apparatus as claimed in claim 5 in which the said predetermined wavelength is the emission wavelength of fluorescent ink with which documents to be read have code markings (2,3) printed thereon.
7. Apparatus as claimed in any one of the preceding claims in which the encoded information is in the format of known barcode codes.
8. Apparatus as claimed in any one of the preceding claims in which documents to be read have a pair of longer edges and a pair of shorter edges and the transport means is adapted to orientate the documents so that either one of a predetermined pair of edges is the leading edge.
9. Apparatus as claimed in any one of the preceding claims in which a plurality of reading stations (4,4') are provided so positioned as to be able to read encoded information irrespective of which way up a document faces.
10. Apparatus as claimed in any one of the preceding claims in which the output of the electronic read means is digitised into a binary coded digital format.
11. Apparatus as claimed in claim 10 in which a neural network (Fig. 5) is provided into which the digitised output of the electronic read means is fed.
12. Apparatus as claimed in claim 11 in which a neural network comprises a plurality of nodes arranged in layers, there being an input layer (51), at least one intermediate layer (52) and an output layer (53), signal connections between every node of every layer and every node of an adjacent layer, means for individually weighting the magnitudes of the signals passed along each connection, and means provided at each node to sum the weighted inputs thereto and provide an output of either '0' or '1' depending on whether the sum is below or above a predetermined threshold value for that node.
13. Apparatus as claimed in claim 12 in which the weighting means is operated to adjust the amount of weighting in accordance with desired criteria.

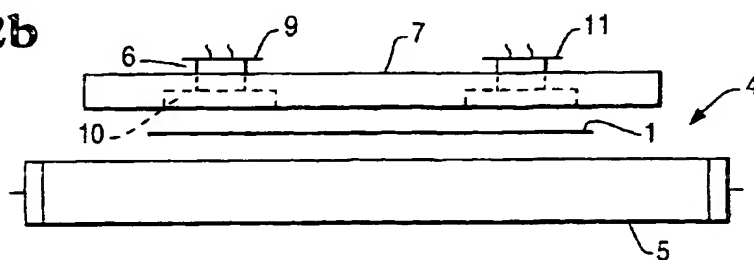
**FIG. 1**



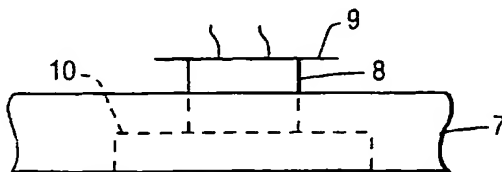
**FIG. 2a**



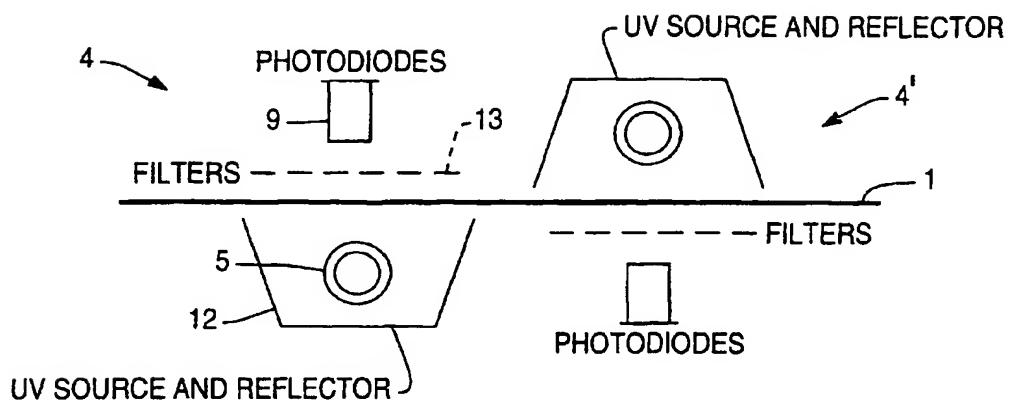
**FIG. 2b**



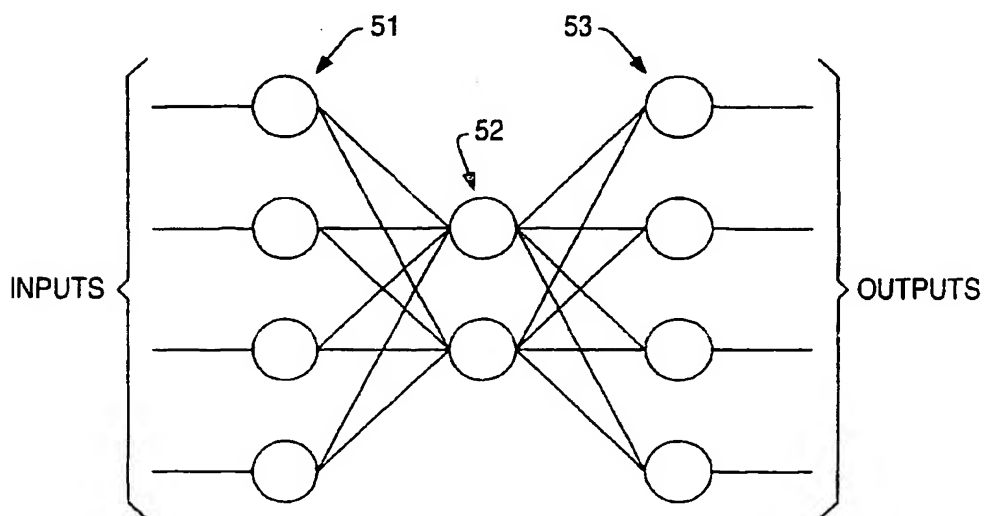
**FIG. 2c**



**FIG. 3**

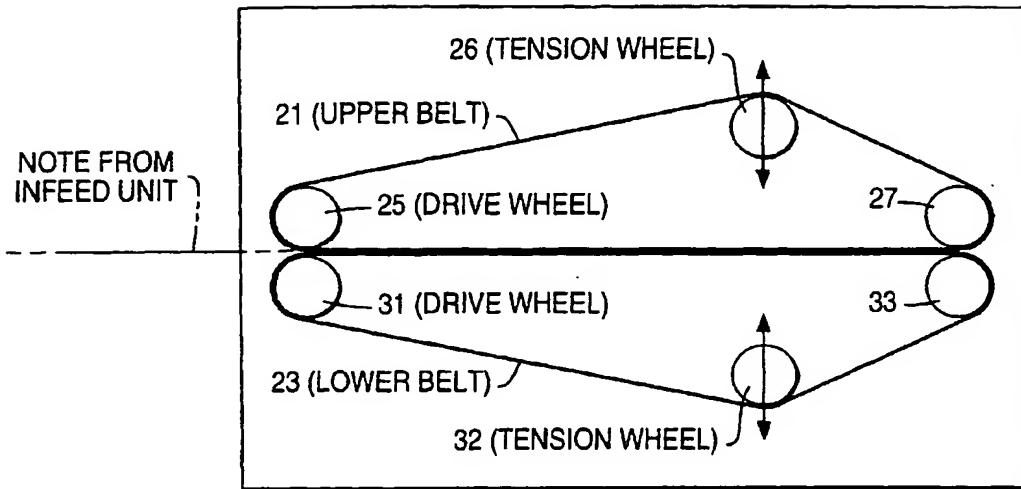


**FIG. 5**



**FIG. 4a**

CUT THROUGH SIDE VIEW



**FIG. 4b**

PLAN VIEW

